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TITLE Pulsed Laser Stereophotography of Plasmas and Dynamically Moving Surfaces

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Pulsed laser stereophotography of plasmas and dynamically moving surfaces

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Abstract

A pulsed laser is used as a light source for illuminating the surface of a dynamic event of <1 mm² moving at >3 mm/µs. At a predetermined time during the dynamic action, a stereo camera is used to record a pair of images of the dynamically moving surface. The stereoimage pair can be quantified for surface contour.

Introduction

Los Alamos has the need to resolve profiles of small dynamically moving surfaces. In most cases the total time of the experiment is <0.5 µs and a profile must be resolved at a predetermined time during the experiment. In many cases the experiment itself is a pseudo-white light emitter, therefore, any light source must be intense, short duration, and separable from the self light of the experiment. A pulsed laser can provide all the attributes necessary for front light reflected stereophotography of our experiments. The attributes desired from the light source include: short pulse (<10 ns), monochromatic, high optical power, and the ability to time synchronize the output pulse. All of these attributes are characteristic of solid state lasers in addition to the spatial coherence that is not desired. As described later, the spatial coherence can be destroyed.

Experimental test device

A small (1 mm x 1 mm) exploding foil is used to accelerate a flyer plate of a dielectric (or dielectric/metal laminate) to a high velocity with a high acceleration, but with a total flight length of only a few millimeters. The metal foil is electrically exploded by a capacitor discharge through the low resistance, low inductance circuit. The exploding foil is the resistive element in the circuit. The high current in a few 10's of nanoseconds rapidly deposits energy in the exploding foil causing rapid heating and conversion of the solid metal to a plasma. The resulting expanding plasma accelerates the flyer plate material at rates exceeding 10^{12} mm/s².

Pulsed laser stereophotographic technique

A cavity dumped ruby laser is used to generate a 5 ns FWHM pulse of 300 mJ. The laser oscillator pulse is then amplified to generate a laser system output a 5 ns pulse of 750 mJ (Fig. 1). Since the laser output pulse is used to illuminate the flyer plate and record a conventional stereopair of photographs, the spatial coherence must be reduced to the point that any speckle is less than the resolution of the film. The speckle reduction is performed by directing the laser pulse through a carbon disulfide cell and fiber optical bundle.[1,2,3] The fiber optical bundle is quadfurcated in order to more evenly illuminate the experiment (Fig. 2).

The stereo camera consists of two identical optical systems with an 18° angle between their optical axes. The camera uses a matched pair of 55 mm f.l. objective lenses removed from a stereomicroscope and remounted and aligned to provide 20X magnification. The film plane is a standard 4 x 5 camera back with a ground glass viewing screen. Between the lenses and film plane is placed a 1 nm FWHM bandpass filter matched to the 694.3 nm of the ruby laser. The output pulse of the laser can be timed within 0.02 µs of the desired time relative to the experiment.

Experimental technique

The exploding foil/flyer plate test device is located with the flyer in the field of view of the camera and the flight path directly toward the stereo camera. The stereo camera will then record the surface of the flyer plate as it approaches the camera. The electrical current and voltage waveforms of the exploding foil and laser output pulse are recorded on digitizers and time correlated to determine electrical and flyer plate relationships (Fig. 3 and Fig. 4).

Quantification of sterophotographs

The stereopair of photographs are quantified by using a stereo comparagraph (Gordon Enterprises Model 121GE) usually intended for aerial photography. The stereo comparagraph was calibrated by photographing a special built stepped wedge that was measured by conventional metrology techniques. The stereo comparagraph was then calibrated against the known dimensions of the wedge. The stereo comparagraph is attached to an X-Y movement with digital readout and the depth (Z-axis) micrometer of the stereo comparagraph was replaced with a digital readout mechanism that permits direct calibration of the reading. Stereophotographs can be read to X-Y-Z position of the flyer surface profile (Fig. 5).

Stereophotographs and quantified results

Typical sets of stereopairs of negatives (Fig. 6) are taken in the static and dynamic condition so as to be able to correlate data between views. Because the surface of the plates do not have features to identify, a white ink is air-brushed on the surface to add features and texture to the surface for future use in quantifying surface profiles. Cross sections of stereopairs can be read (Fig. 7) as well as computer generation of surface profiles based on quantified data (Fig. 8). The resolution and accuracy of the quantified data depend on the quality of the stereophotographs and the ability of the reader, however, values for both resolution and accuracy of ±0.001 in. can and has been obtained.

Summary

Pulsed laser illumination and stereophotography together can provide a unique method of recording three dimensional profiles of events that would normally be obscured by the intense self light of the experiment. High magnification and the velocity of the flyer plate require that the exposure time be short to reduce motion blur to less than the film resolution.

References

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2. Seitz, W., Gardner, S. D., Pulsed Laser Stereophotography of Electrically Exploded Bridges, S.P.I.E. Proceedings 94-14, 1976,
3. Paisley, D. L., Pulsed Laser Stereophotography of Minature Exploding Foils, Proc. of the 12th Int. Congress on High Speed Photography, S.P.I.E. Volume 97, 1976.

Cavity [illegible]

Fig. 2.
Stereo camera with filter [illegible]

Fig. 3.
Digitizers for recording electrical data.

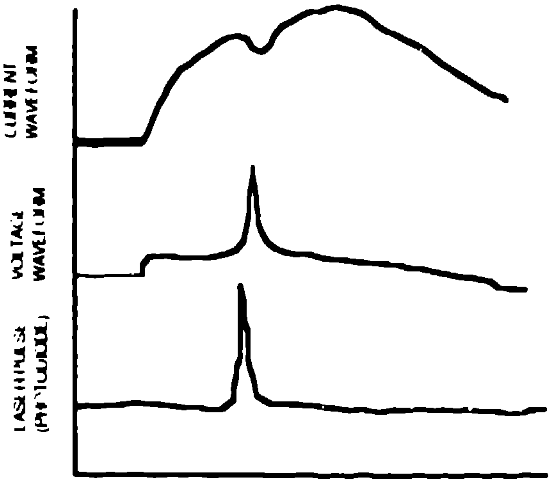

Fig. 4.
Time correlated electrical data with laser pulse.

Fig. 5.
[illegible] used for [illegible] X-Y-Z data.

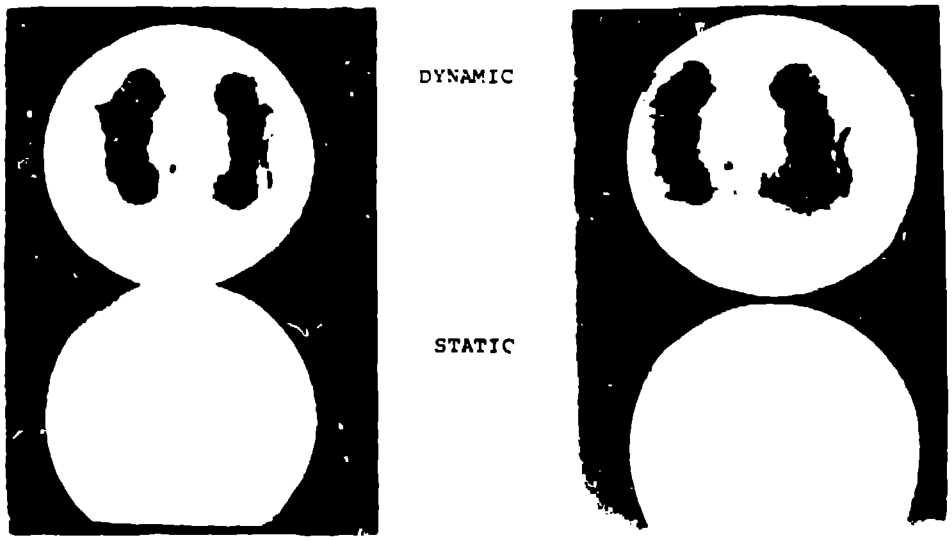

Fig. 6.
Stereo pair of photographs of flyer plate.

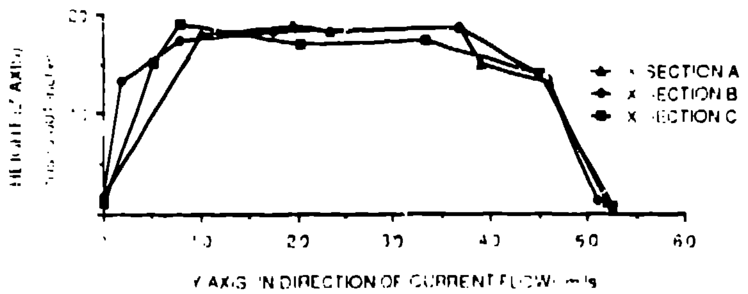

Fig. 7.
Three cross sections [illegible] plane. (Y is vertical and Z is out of page in Fig. 6).

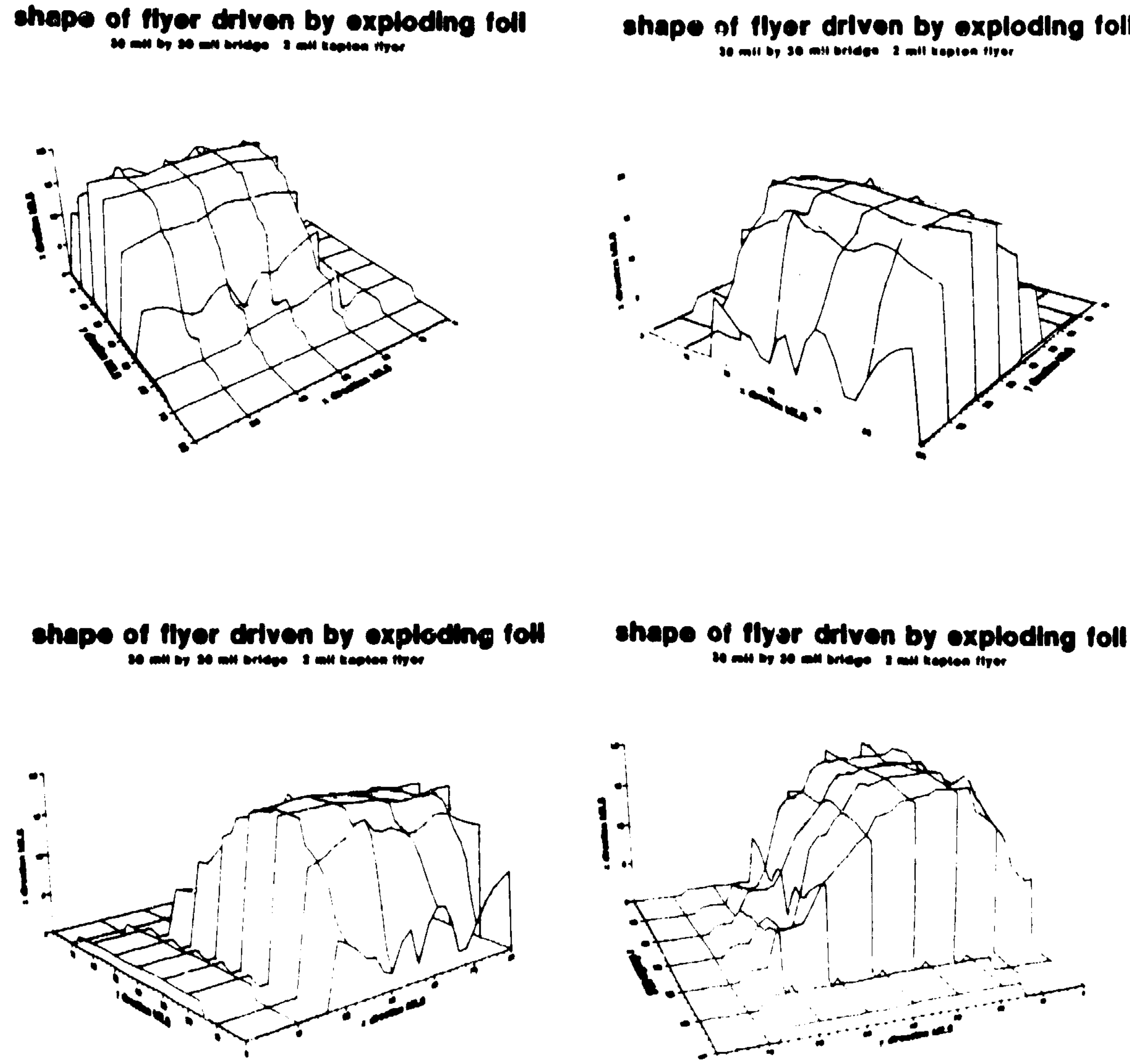

Fig. 3.
Three dimensi[illegible] [illegible]r file from four [illegible]fferent views of data in Fi[illegible].